Measuring topographic change due to splash erosion using Structure from Motion

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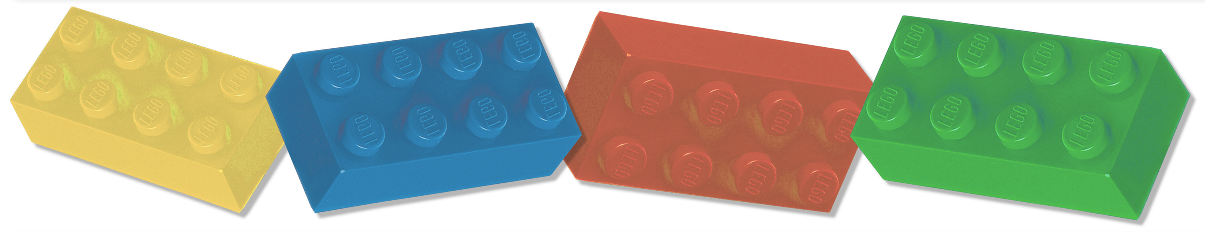


Phase 1: Is SfM accurate enough to be implemented to small-scale geomorphological stidy? If so, how accurate is it?
Phase 2: How can the accuracy of SfM be improved?
Phase 3: How will SfM improve understanding of splash erosion and micro-topographic change?

Introduction

Quantifying surface variability and complexity at the grain-scale is crucial for understanding the characteristic of the erosion interactions since the processes of soil erosion occur at the scale of the individual soil particle (Cooper et al., 2012). Existing methods to characterize the surface roughness are unable to accurately measure the small-scale surface changes that occur due to soil erosion. Furthermore, these methods are expensive both in terms of cost and labour time. In this study, an image-based three-dimensional reconstruction method known as 'Structure from Motion' (SfM) is adopted to acquire a high quality elevation model (DEM) at an exceptionally low cost (Westoby et al., 2012). However, there are still doubts whether the technique is sufficiently accurate. A series of laboratory experiments using LEGO models to quantify the effect of lightning and colouring on SfM accuracy was carried out. Results revealed that lighting, colouring and toning of the image sequence play a significant role on the reconstructed model's accuracy. Being able to improve these conditions improves the accuracy of the models. This technique is applicable when using SfM to study the micro-topography of soil surface.

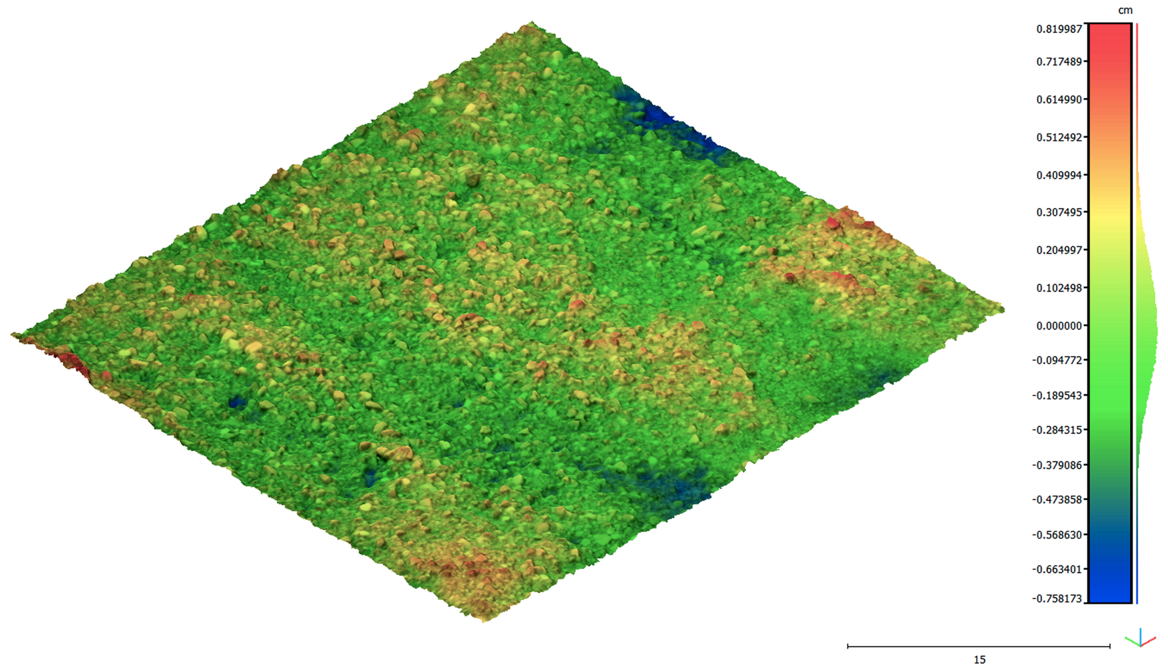


Fig 1 Digital Elevation Model reconstructed using SfM

Why LEGO?

LEGO bricks were used due to their:
- Strong geometrical forms (i.e. sharp edges, rough knobs, square corners)
- Consistency in size (accurate to within 5 µm)
- Basic and universal shape of the bricks make errors illustrate clearly

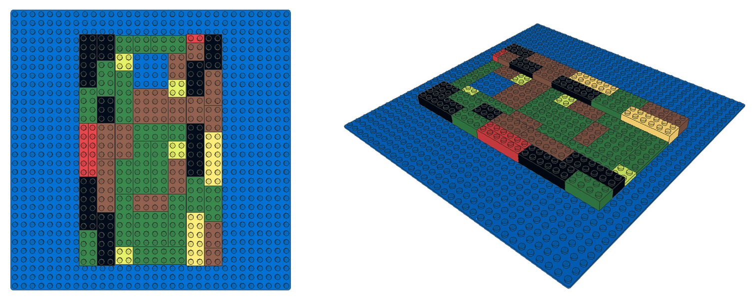
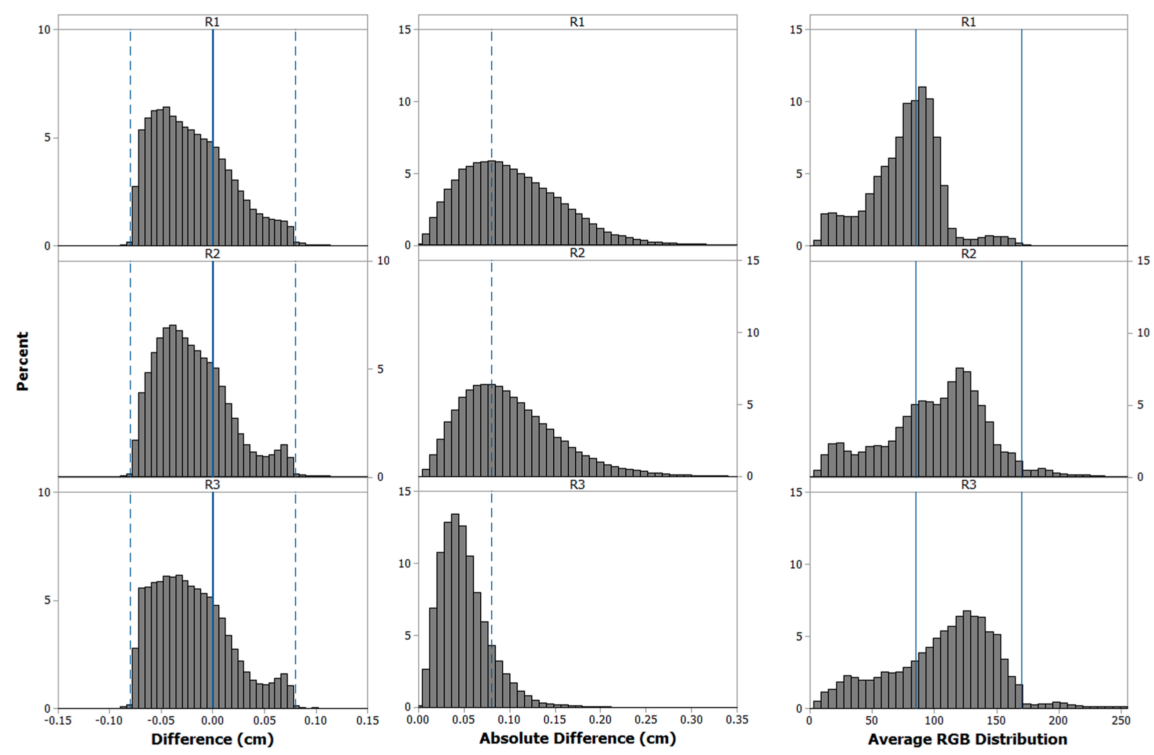


Fig 2 Model used to study the accuracy of SfM (CAD Model)

Accuracy

Fig 3 Output of SfM acquired from different cameras (R1) Sony a6000 with SEL1670z lens, (R2) Apple iPhone5S and (R3) LG Nexus 5



Overall, >50% of the point clouds are less than 0.1cm different from the CAD model; while R3, >90% of the point clouds are less than 0.1cm different.

Fig 4 (Left) Difference (cm) of SfM point clouds when comparing to CAD model. (Middle) Absolute difference (cm) of SfM point clouds from CAD model. (Right) Average RGB of the SfM point clouds.

The results show that the data from the reconstructed model acquired from the LG Nexus 5 (R3) has the highest accuracy. This was due to the poor contrast of the images taken (poor sensor and image processing). However, the 8 MP camera was still able to capture most of the details of the LEGO bricks. This helped the software to match the captured features and produce a well-accurate reconstructed model.

Improving Accuracy

When re-editing model R1 (image sequence taken by Sony a6000) in Adobe Lightroom CC to enhance brighter colour tone, the accuracy of the reconstructed model improved significantly.

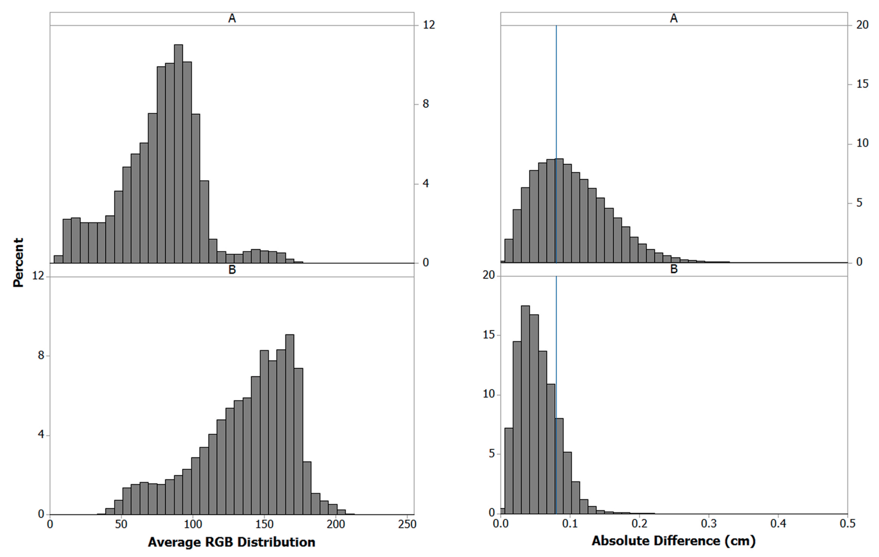


Fig 5 (left) average RGB of the SfM point clouds of model R1 (right) absolute difference (cm) of SfM point clouds when comparing to CAD: (A) oroginal file (B) tone enhanced

Implementation

A sandbox (40x40cm) containing sharp sand with grain size up to 0.5cm was rained over for 8 minutes with 75mm/h intensity to recreate splash erosion. At every 2 minutes, image sequence was taken to process into 3D reconstruction model using SfM in order to evaluate the change of the topography.

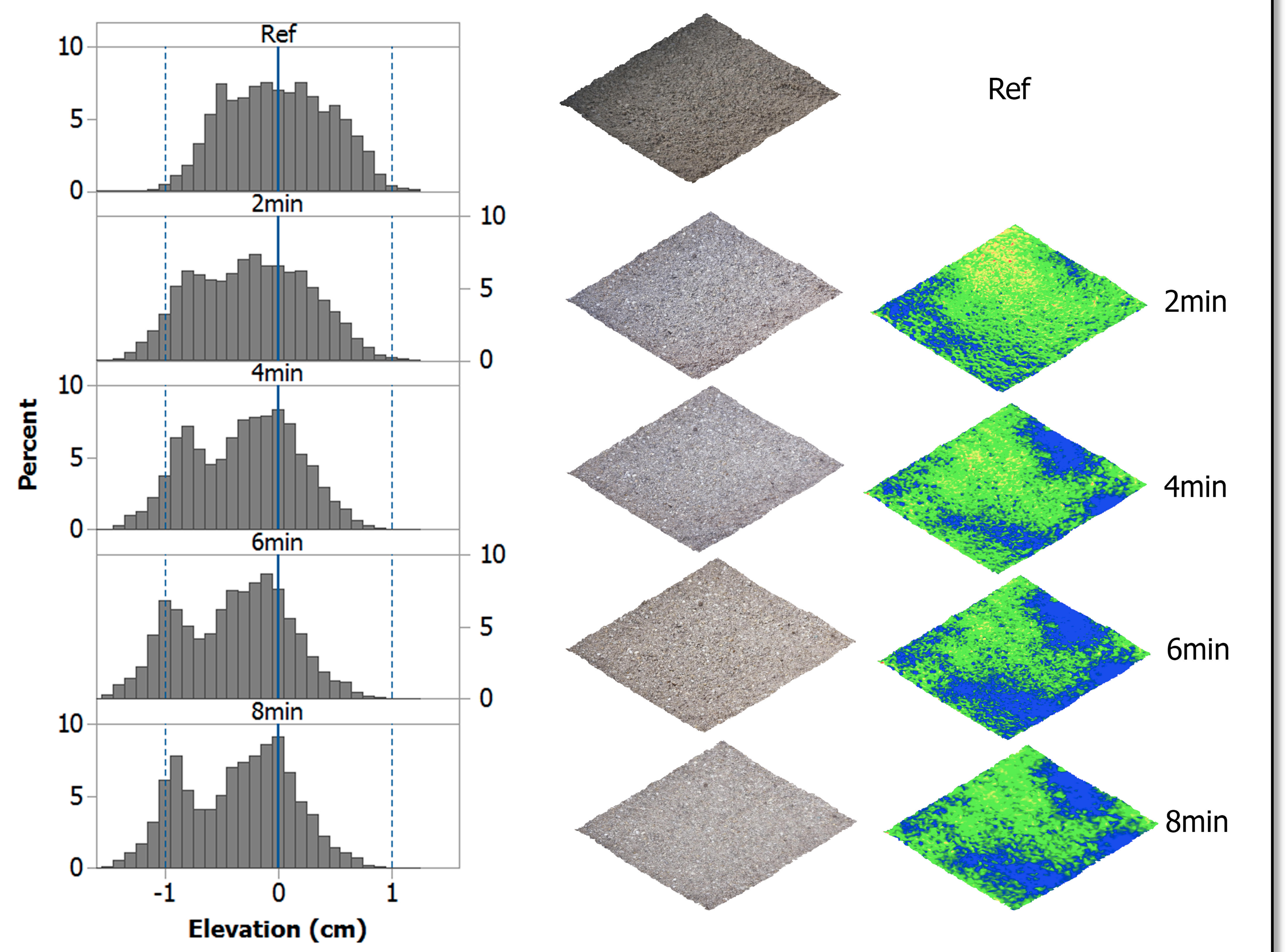


Fig 6 the change of the topography of sand surface after every 2 minutes of simulated rainfall

After every 2 minutes of rainfall, the histograms reports a migration of sediment from higher to lower elevation while the DEMs show the area where erosion occurs. The data illustrate from the histograms correlates to the DEM where darker blue areas are areas with sediment deposition. The changes, though seem dramatic, most are changes lesser than 1cm.

Conclusion

High accuracy of reconstructed models developed from SfM does not require high quality camera, but is highly dependant on the features of the surface the software is able to match. Therefore, being able to reveal features that are hidden by light conditions (shadow) or widen the dinamic range of the image sequence would dramatically improve the accuracy of the reconstructed models. This technique is applicable and highly recommended to geomorphological use of SfM.

Reference

Cooper J. R., Wainwright J., Parsons A. J., Onda Y., Fukuwara T., Obana E., Hargrave G. H. (2012). A new approach for simulating the redistribution of soil particles by water erosion: A marker-in-cell model. Journal of Geophysical Research, 117(F4).
Westoby M.J, Brasington J, Glasser N.F, Hambrey M.J, Reynolds J.M. (2012) 'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. Geomorphology, 179: 300-314.

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